Scheduling Earth Observing Satellites with Evolutionary Algorithms

Al Globus, Gregory Hornby, Jason Lohn and Deepak Srivastava

January 8, 2003

1 Abstract

NASA Ames Research Center has developed the ability to use evolutionary algorithms (EA) for spacecraft antenna design, atomic force field parameter fitting [Globus et al. 2002], analogue [Lohn and Colombano 1998] and digital [Lohn et al. 2002] circuit design, Earth Observing Satellite (EOS) scheduling [Globus et al. 2001], wing design [Pulliam et al. 2003], molecule design [Globus et al. 1999], and aircraft turbine blade design. In some of these areas, evolutionary algorithms match or improve on human performance. Due to space limitations for this abstract, we discuss selected areas:

2 Spacecraft Antenna Design

Designing antennas by hand is slow and requires great expertise. We have automated antenna design using a tree-structured representation which matches the tree-structure of the corresponding antennas. We have evolved small, efficient antennas for NASA's Space Technology 5 mission that, according to simulation, meet the requirements. In addition, the fitness function evaluates an antenna design multiple times, each with a small random perturbation applied to joint angles and wire radii to account for manufacturing tolerances. The addition of manufacturing noise results in antennas that perform well across a broad range of frequencies.

3 Atomic Force Field Parameters

Accurate molecular dynamics simulation of reactive multi-species systems is important for nanotechnology. Unfortunately, reactive multi-species potentials are only available for a few atomic species. Furthermore, developing reactive multi-species potentials is difficult, time consuming, tedious, failure prone and, thus, rarely attempted.

There are two parts to developing any force field: finding a functional form that reflects the physics and choosing the parameters required by the form.

Much of the tedium is in the parameterization. Our EA was able to reproduce the Stillinnger-Weber parameterization for Si [Stillinger and Weber 1990], and generate new parameters for Si and Ge. The new Si parameters matched the energetics of small Si clusters much better than Stillinger-Weber, and the new Ge parameters are the first available for the Stillinger-Weber functional form.

4 References

[Globus et al. 1999] Al Globus, John Lawton, and Todd Wipke, "Automatic molecular design using evolutionary techniques," Nanotechnology, Volume 10, Number 3, September 1999, pp. 290-299.

[Globus et al. 2002] Al Globus, James Crawford, Jason Lohn, and Robert Morris, "Scheduling Earth Observing Fleets Using Evolutionary Algorithms: Problem Description and Approach," Proceedings of the 3rd International NASA Workshop on Planning and Scheduling for Space.

[Globus et al. 2003] Al Globus, Madhu Menon, and Deepak Srivastava, "JavaGenes: Evolving Molecular Force Field Parameters with Genetic Algorithm," Computer Modeling in Engineering and Science, in press.

[Lohn and Colombano 1998] Jason D. Lohn and Silvano P. Colombano, "Automated Analog Circuit Synthesis Using a Linear Representation," Second International Conference on Evolvable Systems: From Biology to Hardware, Springer-Verlag, 23-25 September 1998.

[Lohn et al. 2002] J.D. Lohn, G. Larchev, R. DeMara, "A Genetic Representation for Evolutionary Fault Recovery in FPGAs," International Conf. on Military and Aerospace Programmable Logic Devices, Laurel, MD, September 10-12, 2002.

[Pulliam et al. 2003] Pulliam,Thomas H., Nemec, Marian, Holst, Terry L. and Zingg, D.W., "Comparison of Genetic and Adjoint Methods for Multi-Objective Viscous Airfoil Optimizations," AIAA 2003-0298, AIAA 41st Aerospace Sciences Meeting, Reno, NV, Jan 2003.

[Stillinger and Weber 1990] Frank H. Stillinger and Thomas A. Weber, Dynamical Branching during Fluorination of the Dimerized Si(100) Surface: A Molecular Dynamic Study, Journal of Chemical Physics, 92(10), pages 6239-6245, 15 May 1990.